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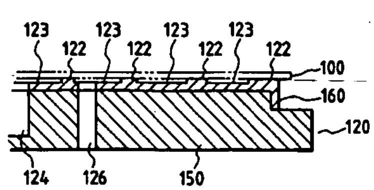
(54) **Treating method and treating apparatus for treated object under reduced pressure environment.**

(57) The object of the present invention is to provide a method of plasma treatment in which wafer temperature control is easily performed and the structure of electrode is simplified. On etching treatment of a wafer, firstly the pressure inside the etching treatment chamber is controlled to a certain pressure, for example above 10 Torr, by means of pumping while the process gas or thermal conductive gas is being introduced into the etching treatment chamber. In this environment, the wafer is mounted on an electrostatic adhering electrode and is electrostatically adhered. The process gas having pressure of approximately 10 Torr is enclosed in the space (reservoir) from the grooves on the electrostatic adhering electrode to the gaps between the wafer lift-up pin. Then, the pressure inside the etching treating chamber is controlled to the etching treating pressure, and etching treatment is performed. The process gas enclosed in the reservoir contributes to cooling of the wafer. After the completion of treatment, the process gas in the reservoir is exhausted with a vacuum pump, the wafer is removed from the electrostatic adhering electrode.

FIG. 17



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Background of the Invention

Field of the Invention

The present invention relates to a method of treating a treated object, such as treating a wafer with plasma, in a reduced pressure environment, and more particularly to a method and an apparatus for treating a treated object in a reduced pressure environment which is easy to perform temperature control of the treated object and suitable for simplifying its electrode construction.

Description of the Related Art

Concerning method of treating a treated object such as a wafer with plasma in a reduced pressure environment, the first prior art proposes that a wafer is mounted on and electrostatically adhered to a specimen table to be treated with plasma, as described in Japanese Patent Publication No.56-53853 (1981) and Japanese Patent Publication No. 57-44747 (1982). The second prior art proposes that a wafer is mechanically held on a specimen table using a clamp and treated while it is being cooled by means of introducing He gas on the bottom surface of the wafer with heat conduction, natural convection and forced convection of the gas, as described in Japanese Patent Publication No. 2-27778 (1990) and Japanese Patent Application Laid-Open No.2-30128 (1990).

Further, the third prior art proposes that a wafer is electrostatically adhered on a specimen table and treated while it is being cooled by means of introducing He gas on the bottom surface of the wafer with heat conduction, natural convection and forced convection of the gas, as described in Japanese Patent Application Laid-Open No.58-32410 (1983) and Japanese Patent Application Laid-Open No.60-115226 (1985).

Furthermore, the fourth prior art proposes that an electrostatic adhering electrode having a diameter larger than the diameter of a wafer to be treated is used as described in Japanese Patent Application Laid-Open No.63-300517 (1988).

When the prior arts described above are applied to an etching treatment in which wafers are successively treated, there arise the following problems to be solved. Firstly, in the first prior art, the wafer being treated cannot be cooled sufficiently, since the heat transfer between the wafer and the specimen table is performed by only solid-solid contact.

Although the second prior art is superior to the first prior art in the wafer cooling characteristics, it has another new problem. The second prior art has a problem in preventing from dust yield since the wafer is mechanically held in its periphery with a clamp to be apt to produce foreign substances due to tipping or deposit attached to the clamp.

The third prior art can prevent from dust yield comparing to the second prior art. However, in the method where the wafer is treated with plasma while the cooling gas is being introduced onto the bottom surface of the wafer as in the second and the third prior arts, control is complex since the pressure on the bottom surface needs to be controlled by means of finely adjusting the in-flow and out-flow rates of cooling gas alternately in order to control the temperature of the wafer to be treated. And the structure is also complex because it is required to provide the specimen table with means for introducing cooling gas.

Furthermore, in the first and the third prior arts, there is a problem in that the temperature rise at the central part of the wafer becomes larger than the peripheral part and the temperature distribution across the wafer becomes non-uniform, since the peripheral part of the wafer is not adhered to the electrostatic adhering electrode, being in a vacuum adiabatic state, and is not cooled. This trend becomes substantially large when the heat input to the wafer increases and the diameter of the wafer increases.

In the fourth prior art, there is a problem in that stable adhering force cannot be obtained and the life of insulating film becomes short, since the diameter of the electrostatic adhering electrode is larger than that of the wafer and the insulating film in the part not adhering the wafer is, therefore, etched and scraped by the plasma.

Summary of the Invention

A first object of the present invention is to provide a method and an apparatus for treating a treated object in a reduced pressure environment in which the temperature control of the treated object is easily performed and the construction of the electrode can be simplified.

A second object of the present invention is to provide an apparatus electrostatically adhering a treated object which is suitable making the temperature distribution across the treated object to be cooled and to

be heat-treated with plasma or the like.

The first object described above can be attained by electrostatically adhering and fixing a treated object to a specimen table after th treat d object is mounted on the specimen table in an environment of a treating system (or a spare chamber or a treating chamber) introduced a gas and controlled to have a pressure higher than treating pressure. Then, the pressure of the treating chamber is controlled to a treating pressure and the treated object is treated. The gas described above may be a process gas or may be a high heat conductive gas such as He.

The second object described above can be attained by means of producing a distribution in the heat transfer coefficient between the wafer and the electrostatic adhering electrode. The following methods can be thought as the method of producing the distribution: forming wafer contact portions and wafer non-contact portions alternately with varying the gap between the wafer and the insulating film; forming large roughness portions and small roughness portions on the surface of the insulating film alternately; and forming the insulating film using different kinds of materials alternately.

According to the present invention, by means of electrostatically adhering a treated object such as wafer in an environment controlled to a pressure higher than a treating pressure, a gas having a pressure higher than the treating pressure can be enclosed in a space between the treated object and the specimen table. And then the pressure of the treating chamber is controlled to the treating pressure and the treated object is treated. During this time, the gas pressure is gradually decreased since the gas enclosed between the treated object and the specimen table leaks into the treating chamber through the gap formed by the surface roughness between the treated object and the specimen table. However, by means of adjusting the enclosing pressure and the electrostatic adhering force, it is possible to keep the gas pressure high enough to produce sufficient heat transfer coefficient for cooling or heating the treated object during treatment.

Explanation will be made next on a case where the gap between the wafer and the electrostatic adhering electrode is varied alternately to form contact portions and non-contact portions on the wafer. The heat transfer coefficient between the wafer and the electrode is high at the contact portions on the wafer and low at the non-contact portions on the wafer. Therefore, the temperature of the wafer is low at the center of the contact portion and high at the center of non-contact portion. Since the temperature distribution in the wafer falls within the difference between the highest temperature at the center of the wafer contact portion and the lowest temperature at the center of the wafer non-contact portion, the temperature in the periphery is prevented from solely rising higher comparing to the temperature at the center and from forming a non-uniform temperature distribution as observed in a conventional apparatus. Thus the uniform temperature distribution can be obtained. On addition to this, since the heat transfer coefficient depends on the electrostatic adhering force, the same effect can be obtained by means of varying the surface roughness of the insulating film alternately or by means of varying the kinds of materials of the insulating film.

Brief Description of the Drawings

FIG.1 is a view showing the construction of an etching apparatus to which a first embodiment in accordance with the present invention is applied.

FIG.2 is a view showing the construction of an etching treating chamber to which the first embodiment is applied.

FIG.3 is a view showing the construction of a bottom electrode and an electrostatic adhering electrode in the first embodiment.

FIG.4 is a view showing the construction of a bottom electrode and an electrostatic adhering electrode in the first embodiment.

FIG.5 is a chart explaining the etching treatment in the first embodiment.

FIG.6 is a graph showing a relationship between gas pressure and heat transfer coefficient.

FIG.7 is a view showing the construction of an etching treating chamber to which a second embodiment in accordance with the present invention is applied.

FIG.8 is a chart explaining the etching treatment in the second embodiment.

FIG.9 is a view showing the construction of an etching treating chamber to which a third embodiment in accordance with the present invention is applied.

FIG.10 is a view showing the construction of an etching treating chamber to which a fourth embodiment in accordance with the present invention is applied.

FIG.11 is a chart explaining the tching tr atment in the fourth embodiment.

FIG.12 is a view showing the construction of anther etching apparatus to which a fifth embodiment in accordance with the pr sent invention is applied.

FIG.13 is a view showing the construction of a spattering apparatus to which a sixth embodiment in accordance with the present invention is applied.

FIG.14 is a view showing the construction of a spattering apparatus to which a seventh embodiment in accordanc with the present invention is appli d.

FIG.15 is a cross-sectional view being taken on the plane of the line A-A in FIG.14.

FIG.16 is a plan view of an electrostatic adhering electrode to which an eighth embodiment in accordance with the present invention is applied.

FIG.17 is a side view of the electrostatic adhering electrode in FIG.16.

FIG.18 is a graph showing calculated results of the heat transfer coefficient in the embodiment in FIG.16.

FIG.19 is a graph showing calculated results of temperature distribution across the wafer in the embodiment in FIG.16.

Detailed Description of the Preferred Embodiments

Description will be made below on the construction of a microwave etching apparatus with magnetic field to which a first embodiment according to the present invention is applied, referring to FIG.1 to FIG.4. Firstly, transfer of a wafer 1 will be described below referring to FIG.1. The wafer 1 is take out of a load cassette 3 using a linear driving arm 2 to be carried into a load lock chamber 4. Then, the wafer 1 carried in the load lock chamber 4 is carried inside a buffer chamber 5, which is vacuum environment, toward a etching treatment chamber 6 using a rotating arm 7. After being etched in a manner to be described later, the wafer 1 is take out to the atmosphere through the buffer chamber and an unload lock chamber 8 to contained into an unload cassette 9.

The etching treatment camber 6 will be described below referring to FIG.2. Etching treatment of the wafer 1 is carried out in such a manner that a given amount of process gas 11 introduced into a discharge tube 10 is formed into plasma 14 with the interaction of magnetic fields cased by microwave 12 and a solenoid coil 13, the energy of ion to be implanted into the wafer 1 being controlled using a bottom electrode 15 applying high frequency current from a high frequency power source 16, the bottom electrode 15 being controlled its temperature by means of circulating a coolant 18 using a circulator 17.

There is provided on the bottom electrode 15 an electrostatic adhering electrode 21 which is constructed by means of forming an insulating film 20 on an aluminum electrode 19. A switch 23 and a direct current power source 24 are connected to the bottom electrode 15 through a low pass filter 22. During etching treating the wafer 1 is held in such a manner that the bottom electrode 15 is lifted up to fix the periphery of the wafer 1 with a wafer clamp 25, plasma 14 being produced in the manner described above, and then the switch 23 is turned on in order to apply direct current to the both sides of the insulating film 20 to produce electrostatic adhering force.

Next, the constructions of the bottom electrode 15 and the electrostatic adhering electrode 21 will be described referring to FIG.3 and FIG.4. A hole 27 is formed in the bottom electrode 15 and the electrostatic adhering electrode 21 at the center of the surface mounting the wafer in the direction of the wafer thickness. A wafer lift-up pin 26 is inserted into the hole to lift up the wafer 1 from the electrostatic adhering electrode 21 in order to transfer the wafer 1.

A plurality of grooves 28 radially extending from the hole 27 and a plurality of ring-shaped grooves 29 connecting the grooves 28 each other are formed on the surface mounting the wafer 1 of the electrostatic adhering electrode 21. These groves 28 and 29 have, for example, a depth of 0.05 to 0.1mm and a width of 0.5 to 1.0mm, and are formed with ultrasonic machining. One end of the wafer lift-up pin 26 is supported with a sliding baring 30 and the other end is sealed with an O-ring 31. And a plurality of gaps 32 (communicating passages) are provided on the outer surface of the sliding baring 30. Therewith, when the wafer 1 is not mounted on the electrostatic adhering electrode 21, the space (reservoir) from the grooves 28 and 29 on the electrostatic adhering electrode 21 to the gaps between the wafer lift-up pin 26 and the hole 27 is communicating to the etching chamber 6. The bottom electrode 15 is provided with an exhausting hole 33 which is connected up to the gap between the wafer lift-up pin 26 and the hole 27 in order to evacuate the etching chamber 6 using a vacuum pump 36 through a valve 35 by means of opening a valve 34.

Th sequence of etching treatment in a first embodiment according to the present invention will be described below referring to FIG.5. Firstly, the pressure inside the etching treatment chamber is controlled to a certain pressure, for xample above 10 Torr, by means of pumping while the process gas 11 is being introduced into the etching treatment chamber 6. Ther with, the pressure, in the space (reservoir) from the grooves 28 and 29 on the lectrostatic adhering electrode 21 to the gaps between the wafer lift-up pin 26

and the hole 27 which is communicated to the etching treatment chamber 6, becomes above 10 Torr.

Generally, the relationship between gas pressure and heat transfer coefficient is such a relationship as in helium gas shown as an example in FIG.6, the heat transfer coefficient does not depend on th pressure and has a constant value in th range from several Torrs to approximately 10 Torrs. On the other hand, the treating pressure is approximately 0.01 Torr for etching or chemical vapor deposition, and approximately 0.1 Torr for spattering, $1/10^5$ to $1/10^7$ Torr for ion implanting, and approximately $1/10^{10}$ Torr for molecular beam epitaxy. Therefore, a stable and high heat transfer coefficient can be obtained when the pressure is higher than the treating pressure, that is above 0.1 Torr or preferably approximately above 10 Torr.

The wafer 1 is transferred to the etching treatment chamber 6 using the rotating arm 7 under such a gas pressure higher than the treating pressure, the wafer lift-up pin 26 being raised to lift up the wafer 1, the rotating arm 7 being rotated to the load lock chamber 4 side, and then the wafer lift-up pin 26 is lowered. Therewith, the wafer 1 is mounted on the electrostatic adhering electrode 21.

The bottom electrode 15 is raised to hold the periphery of the wafer 1 with the wafer clamp 25. Under this condition, the plasma 13 is generated by turning on the microwave 12 and the solenoid coil 13, and the switch 23 is turned on to electrostatically adhere the wafer 1 onto the electrostatic adhering electrode 21. By doing this, The process gas having a pressure above approximately 10 Torr is enclosed in the reservoir that is the space from the grooves 28 and 29 on the electrostatic adhering electrode 21 to the gap between the wafer lift-up pin 26 and the hole 27, and the pressure in the reverse side of the wafer 1 is approximately 10 Torr.

After the microwave 12 is turned off for a moment to eliminate the plasma 14 and the switch 23 is turned off, the pumping rate of the process gas 11 from the inside of the etching treatment chamber 6 is increased and the pressure is controlled to the etching treatment pressure which is lower than the pressure at the beginning. During this time, the wafer 1 is held with the residual adhering force, the process gas 11 existing in the space from the grooves 28 and 29 on the electrostatic adhering electrode 21 to the gap between the wafer lift-up pin 26 and the hole 27 being leaking to the etching treatment chamber 6 through the gap having a width of surface roughness between the reverse side surface of the periphery of the wafer 1 and the peripheral surface of the electrostatic adhering electrode 21, and the process gas 11 excluding this leaked amount is enclosed in the gap.

Next, the microwave 12 is again turned on to produce plasma and the switch 23 is turned on, then the wafer is given the adhering force to be treated under this condition. During etching treatment of the wafer 1, the process gas in the reservoir, that is the space from the grooves 28 and 29 of the electrostatic adhering electrode 21 to the gap between the wafer lift-up pin 26 and the hole 27, is leaking due to the pressure difference between in the etching treatment chamber 6 and in the space. Although the pressure in the space is gradually decreasing, the pressure is kept high enough to be required to maintain the temperature of the wafer 1 at a given temperature during the etching treatment.

After completion of the etching treatment, the process gas 11 in the reservoir, that is the space from the grooves 28 and 29 on the electrostatic electrode 21 to the gap between the wafer lift-up pin 26 and the hole 27, is evacuated by opening the valve 34 using the vacuum pump 36. Then the microwave 12 and the solenoid coil 13 are turn off to eliminate the plasma 14 and the switch 23 is turned off to release the electrostatic adherence force act on the wafer 1. And the bottom electrode 15 is lowered to release the wafer 1 from clamping of the wafer clamp 25.

Table 1 shows a result of an experiment on the temperature change of a wafer 1 during etching treatment in accordance with this etching method.

Table 1

Measured Results of Wafer Temperature Change HEAT INPUT:120W/6in

WAFER BEND (μm)	APPLIED VOLTAGE (V)	PRESSURE ON REVERSE SURFACE BEFORE BEGINNING OF ETCHING (Torr)	PRESSURE ON REVERSE SURFACE 2 MIN AFTER BEGINNING OF ETCHING (Torr)	WAFER TEMPERATURE DURING ETCHING (°C)
5	-300	10.4	9.2	0.6
	-600	10.4	9.5	0.5
30	-300	10.4	6.3	2.7
	-600	10.4	9.4	0.4

According to the result, when the bending amount (convex shaped) of the wafer 1 is small namely approximately 5 µm and the voltage applied to th electrostatic adhering electrode 21 is above -300V, the temperature change of the wafer 1 during etching treatment is within approximately 1 • C and, therefore, a preferable result has been obtained. When the bending amount (convex shaped) of the wafer 1 is large namely approximately 30 µm and the voltage applied to the electrostatic adhering electrode 21 is above -300V, the temperature change of the wafer 1 during etching treatment is approximately 2.7 • C. Even in this case, the applied voltage is, however, increased up to -600 • C to increase adherence force, the temperature change can be decreased within 1 • C and a preferable result has been also obtained. In this time, the heat input to the wafer 1 has been approximately 120W/6inches.

The treatment temperature of the wafer 1 can be set by means of changing the pressure on the reverse side surface of the wafer 1 at the initial period of the electrostatic adherence of the wafer 1 and changing the pressure on the reverse side of the wafer 1 at the beginning of etching treatment. The sufficient repeatability of the temperature of the wafer 1 can be easily obtained by means of providing a pressure gage between the exhausting hole 33 and the valve 34 and controlling the pressure at the beginning of etching treatment at a constant value.

Helium gas instead of the process gas 11 may be used as the gas enclosed in the reservoir that is the space from the grooves 28 and 29 on the electrostatic adhering electrode 21 to the gap between the wafer lift-up pin 26 and the hole 27. In this case, as the first step, the helium gas is introduced into the etching treatment chamber 6. And after completion of electrostatic adherence, the process gas is introduced into the etching treatment chamber 6 instead of helium gas. Then after the pressure is controlled to the etching treatment pressure, etching treatment is performed as described above.

Description will be made below on the construction and etching method of a microwave etching apparatus with magnetic field to which a second embodiment according to the present invention is applied, referring to FIG.7 and FIG.8. The different point in this construction from that in the first embodiment is that the bottom electrode 15 is provided with an electrode 38 which is capable of being switched between the ground and floating state using a switch 37 and contacted to the reverse surface of the wafer 1 when the wafer is mounted on the electrostatic adhering electrode 21. The electrostatic adherence of the wafer 1 is carried out by means of switching on the switch 23 under the condition of switching on the switch 37. And when the etching treatment is started, the switch 37 is turned off to make the electrode 38 to a floating state. By doing this way, the release of electrostatic adherence of the wafer 1 can be eliminated when the pressure inside the etching treating chamber is controlled to the treating pressure before starting the etching treatment as shown in FIG.8, which leads to lessening in pressure decrease on the reverse side surface of the wafer.

Description will be made below on the construction and etching method of a microwave etching apparatus with magnetic field to which a third embodiment according to the present invention is applied, referring to FIG.9. The different point in this construction from that in the first and the second embodiments is that the electrode 19 in the electrostatic adhering electrode 21 is divided into two parts 19A, 19B insulated from each other, switches 39 and 40 being connected to direct current power sources 41 and 42 so that direct current voltages having the opposite polarities may be applied to the electrodes 19A and 19B each. Adhering of the wafer 1 is performed by turning on the switches 39 and 40. By doing this, as shown in FIG.8, the electrostatic adhering force acting on the wafer 1 does not released when the pressure inside the etching treatment chamber 6 is controlled to the treating pressure before the etching treatment of the wafer 1. Therefore, in this case, the same effect as in the second embodiment can also be attained.

Description will be made below on the construction and etching method of a microwave etching apparatus with magnetic field to which a fourth embodiment according to the present invention is applied, referring to FIG.10 and FIG.11. The different point in this construction from that in the first and the second embodiments is that an O-ring 40 is provided in the periphery of surface of an etching electrode 39, the bottom electrode 15 being raised after the wafer 1 is mounted on the etching electrode 39, the wafer 1 during etching treatment being held with the wafer clamp 25. By doing this, as shown in the sequence in FIG.11, the etching treatment of the wafer 1 can be done by means of controlling the pressure inside the etching treatment chamber 6 to the treating pressure after the wafer 1 is held with the wafer clamp 25 in the same way as in the embodiments described above.

FIG.12 shows a fifth embodiment, as another etching apparatus, in which the present inv ntion is applied to a parallel plain plate type reactive ion etching apparatus. The different point from the microwave etching apparatus with magnetic field is that there is provided an upper electrode 41 which is connected to the ground and facing against th bottom electrod 15, and high frequency current is appli d to both of the electrodes with a high frequency power source 16 to produce plasma 14 inst ad of producing plasma 14

with the interaction of the microwave 12 and the magnetic field induced by the solenoid coil 13.

The different points among the first, the second and third embodiments are in the methods of plasma production. Therefore, the etching treatment can be also performed in the same way by forming the bottom electrode 15 in the same construction as in the embodiments described above.

FIG.13 shows the construction of a sixth embodiment in which the present invention is applied to a spatter apparatus. The spatter apparatus has a target 42 for forming film mounted on the upper electrode 41, a wafer 1 being mounted on the bottom electrode 15 which has a heater 43 for heating the wafer 1, high frequency current being applied between the upper electrode 41 and the bottom electrode 15 to produce plasma 14, and then a shutter 44 is opened to form a film of the target 42 on the surface of wafer 1. The different points from the etching apparatus are that the treatment pressure is further lower and the wafer 1 is treated while being heated. Therefore, the spattering treatment can be also performed in the same way as described above by forming the bottom electrode 15 in the same construction as in the first, the second and the third embodiments.

The construction of the reservoir to hold a part of the treating gas is not limited to the embodiments described above. For example, the construction of the reservoir may be such that a space having a certain volume is provided and a concave part opening to the surface of electrostatic adhering electrode, that is the surface exchanging heat with a wafer, is separately provided from the electrostatic adhering electrode 21.

FIG.14 and 15 show the construction of a seventh embodiment in which the present invention is applied to a treatment apparatus having a plurality of treating chambers. FIG.15 is a cross-sectional view being taken on the plane of the line A-A in FIG.14. Explanation will be made on a case the present invention is applied to a spattering apparatus as an example of the apparatus.

The spattering apparatus comprises spare chambers: a wafer load/unload chamber 45, a loading chamber 46; and treating stations: a second treating station 47, a third treating station 48, a fourth treating station 49 and a fifth treating station 50. The apparatus also has a transfer mechanism 51 to transfer the wafer 1 between the both spare chambers, that are the wafer load/unload chamber 45 and the loading chamber 46. The apparatus has five sets of wafer holder 54 (wafer holders 54 in the second treating station 47, the third treating station 48 and the fifth treating station 50 are not shown in the figure) moving forward and backward toward the loading chamber 46 and the treating chambers (the stations from the second treating station 47 to the fifth treating station 50) by means of a circular cone cam 53 being moved upward and downward using an air cylinder 46. The apparatus has means for transferring the wafer which comprises a drum 58 driven by a motor 55, a gear 56 and a chain 57 to rotate the wafer holder 54 step-wise with a pitch between treating stations; a wafer chuck mechanism (not shown) to transfer the wafer 1 from the transfer mechanism 51 to the wafer holder 54 in the loading chamber 46. Furthermore, the apparatus has a vacuum pump 59 to evacuate the wafer load/unload chamber 45; a leak valve 60 to release the vacuum to the atmosphere; a vacuum pump 61 to evacuate the loading chamber 46 and the treating chambers from the second treating station 47 to the fifth treating station 50; a valve 63 to release the vacuum to the atmosphere or to introduce process gas 62 such as argon gas.

The wafer 1 to be treated is transferred through a gate valve 64 into the wafer load/unload chamber 45 having been released to the atmosphere by means of opening the leak valve 60. When the wafer load/unload chamber 45 is evacuated using the vacuum pump 59 and the pressure in the wafer load/unload chamber reaches approximately that in the loading chamber 46, a gate valve 65 is opened to transfer the wafer into the loading chamber 46 using the transfer mechanism 51.

In the loading chamber 46, the wafer 1 having been transferred from the wafer chuck mechanism to the wafer holder 54 is preformed given treatments at the stations between the second treating station 47 to the fifth treating station 50 by rotating the drum 58. Then the wafer 1 having treated is transferred through the loading chamber 46 to the wafer load/unload chamber 45 and is unloaded out of the wafer load/unload chamber 45 in the processes reverse to those described above.

At the stations between the second treating station 47 and the fifth treating station 50, the treatments are performed with arbitrary combination of wafer baking treatment to remove contamination gas absorbed on the surface of the wafer 1; spatter etching treatment to remove oxide layer on the surface of the wafer 1 before spattering; spattering treatment to form a thin film. In general, wafer baking treatment is performed at the second treating station 47, spatter etching at the third treating station 48, and spattering treatment at the fourth treating station 49 and the fifth treating station 50. In this case, treating units 66 at each of the stations are that the unit in the second treating station 47 is a wafer baking unit, in the third teaming station 48 being a spatter etching unit, in the fourth treating station 49 and in the fifth treating station 50 being spatter treating units.

In this embodiment, the waf r holder 54 has a structure to hold the wafer 1 with electrostatic adherence as shown in the second embodiment according to the present invention, and in the spare chamber, that is

the loading chamber 46, process gas 62 such as argon or helium gas is enclosed on the reverse side surface of the wafer 1 through the same processes as thos in the second embodiment. Then, the treating temperatures of the wafer 1 can be controlled by means of successiv ly performing wafer baking treatment, spatter etching treatment and spattering treatment in the treating chambers.

As described above, the present invention can be widely applied to the temperature control of treated object in a treatment apparatus in which a specimen such as wafer is treated with plasma or the like in a reduced pressure environment while the specimen is being cooled or heated. It can be cited plasma etching, plasma chemical vapor deposition, spattering and so on as the examples of treating a treated object using plasma. It can be cited ion implantation, molecular beam epitaxy, vapor deposition, reduced pressure chemical vapor deposition and so on as the examples of treating a treated object not using plasma.

And it can be cited etching, ion implantation, spattering, ion milling, electron beam machining, lithography and so on as the examples of cooling a specimen. It can be cited chemical vapor deposition, molecular beam epitaxy, vapor deposition and so on as the examples of heating a specimen.

Explanation will be made below on the construction of a electrostatic adhering electrode to which an eighth embodiment according to the present invention is applied, referring to FIG.16 and FIG.17. The direction of the orientation flat 140 of a wafer 100 to be treated etching is adjusted in advance so as to engage to the orientation flat 130 of an electrostatic adhering electrode 120. Then the wafer is mounted on the electrostatic adhering electrode 120 constructed by forming an insulating film 160 of Al_2O_3 on the surface of an aluminum electrode 150 in an etching treating chamber. The electrostatic adhering electrode has an insulating film 160 which is formed by thermal splay of Al_2O_3 on the surface of an aluminum electrode 150 in a reduced pressure environment. Etching treatment of the wafer 100 is preformed in such a manner that the process gas introduced in a discharge tube is made into plasma with the interaction of microwave and the magnetic field induced by a solenoid coil, high frequency current being applied to an electrode fixing the electrostatic adhering electrode 120 with a high frequency power source to control the energy of ions to be implanted into the wafer 100.

After completion of etching treatment of the wafer 100, the wafer 100 is removed from the electrostatic adhering electrode 120 by means of raising a lift-up pin, and then transferred to another place by a transfer mechanism.

The electrostatic adhering electrode 120 has approximately the same outer diameter as the wafer 100, and has the orientation flat 130 in the periphery. And on the surface of the wafer 100, there are alternately arranged ring-shaped wafer contact portions 122 and ring-shaped wafer non-contact portions 123. The ring-shaped adhering portions attaches to the wafer 100, and the ring-shaped non-adhering portions are grooves having a depth of approximately 100μm. A reservoir 124 for storing helium gas is provided on the upper surface of the electrostatic adhering electrode 120 so as to open upward. Grooves 125 having depth of approximately 100μm are also provided on the upper surface of the electrostatic adhering electrode 120. The grooves 125 are flow passages through which the helium gas stored in the reservoir 124 flows toward the periphery of the electrostatic adhering electrode, and are also formed with ultrasonic machining. A hole for a lift-up pin 126, which is not shown in the figure, is sealed so that the helium gas may be leaked.

FIG.18 shows measured results of heat transfer coefficients between the wafer 100 and the electrostatic adhering electrode 120 in the wafer contact portion 122 and the wafer non-contact portion 123. Although both of the heat transfer coefficients in the wafer contact portion 122 and in the wafer non-contact portion 123 are increased with increase in the pressure on the reverse side surface, the heat transfer coefficient in the wafer contact portion 122 is larger than that in the non-adhering portion 123. When the pressure on the reverse side surface is approximately 4 Torr, the heat transfer coefficients in the wafer contact portion and in the wafer non-contact portion are approximately 600W/m^{2}K and approximately 200W/m^{2}K respectively.

FIG.19 shows calculated results of temperature distributions in the radial direction of the wafer 100 for a conventional technique and for the present invention during etching treatment based on the results described above. In these calculations, it is assumed that the wafer size has a diameter of 8 inches, the heat input to the wafer being 200W, the heat transfer coefficient in the adhering portion 122 being 600 W/m^{2}K, the heat transfer coefficient in the non-adhering portion 123 being 200 W/m^{2}K, the heat transfer coefficient in the non-adhering portion on the periphery of the wafer being 0 W/m^{2}K.

In the conventional technique, the temperature rise is large since the adiabatic area of the wafer in the periphery is large, and the temperature difference becomes ±2.5 °C. On the other hand, in the present invention, although the av rage temperatur is higher, the temperature distribution alternately changes high and low in the direction of the radius and the temperature difference is decreased to ±0.75 °C.

With varying the heat transfer coefficient between the wafer 100 and the electrostatic adhering lectrode 120 by means of forming high heat transfer coefficient portions and low heat transfer coefficient portions

alternately, the temperature distribution across the wafer 100 can be flattened. The same effect can be obtained with varying electrostatic adhering force by means of alternately varying the surface roughness of the insulating film 160 large and small or by means of alternately varying the film materials of the insulating film 160. Although it has been described in th mbodiment that helium gas is enclosed in the reservoir 124, the same effect can be obtained when the other kind of gas is used.

According to the present invention, in a method of treating a treated object in a reduced pressure environment, it can be realized easily performing the temperature control of the treated object and simplifying its electrode construction.

Further, according to the present invention, the temperature distribution across a treated object treated in a reduced pressure environment can be made more uniform.

Claims

1. A method of treating a treated object under a reduced pressure environment, which comprises:
   a process for electrostatically adhering a treated object to a specimen table after the treated object is mounted on the specimen table in a gas environment of a treating system having pressure higher than treating pressure;
   a process for controlling the pressure of a treating chamber to a given treating pressure;
   a process for treating said treated object under said treating pressure in said treating chamber.

2. A method of treating a treated object under a reduced pressure environment, which comprises:
   a process for electrostatically adhering a treated object to a specimen table after the treated object is mounted on the specimen table in a gas environment of a treating chamber having pressure higher than treating pressure;
   a process for controlling the pressure of said treating chamber to a given treating pressure;
   a process for treating said treated object under said treating pressure in said treating chamber.

3. A method of treating a treated object under a reduced pressure environment, which comprises:
   a process for electrostatically adhering a treated object to a specimen table after the treated object is mounted on the specimen table in a gas environment of a spare treating chamber having pressure higher than treating pressure;
   a process for controlling the pressure of a treating chamber to a given treating pressure;
   a process for treating said treated object under said treating pressure in said treating chamber.

4. A method of treating a treated object under a reduced pressure environment, which comprises:
   a process for electrostatically adhering a treated object to a specimen table having a reservoir after the treated object is mounted on the specimen table in a gas environment of a treating system having pressure higher than treating pressure;
   a process for controlling the pressure of a treating chamber to a given treating pressure;
   a process for transmitting heat between said specimen and said specimen table using said gas enclosed in said reservoir as well as for treating said treated object under said treating pressure in said treating chamber.

5. A method of treating a treated object under a reduced pressure environment according to any of claim 1 through claim 4, wherein said method of treating the treated object is a plasma treating method treating the treated object with plasma.

6. A method of treating a treated object under a reduced pressure environment according to any of claim 1 through claim 4, wherein said method of treating the treated object is an ion implantation treating method treating the treated object with ion implantation.

7. A method of treating a treated object under a reduced pressure environment according to any of claim 1 through claim 4, wherein said method of treating the treated object is a treating method treating the treated object with molecular beam epitaxy.

8. A method of treating a treated object under a reduced pressure environment according to claim 4, wherein the heat transmission between said specimen and said specimen table using said gas enclosed in said reservoir is that the heat gen rated in the treated object by the plasma treatment is

transmitted to said specimen table.

9. A method of treating a treated object under a reduced pressure environment according to any of claim 1 through claim 4, wherein said specimen table comprises an electrostatic adhering electrode having grooves on its surface and a hole for a pin for lifting up the specimen, and gas having a pressure higher than said treating pressure is enclosed between said wafer and the space that is formed from the grooves on said electrostatic adhering electrode to the gap between the pin to lift up the specimen and the hole.

10. A method of treating a treated object under a reduced pressure environment according to any of claim 1 through claim 4, wherein said pressure higher than the treating pressure is higher than 10 Torr.

11. A method of treating a specimen with plasma, which comprises:
 a process for mounting a specimen on a specimen table having a reservoir in a gas environment of a treating system having pressure higher than treating pressure;
 a process for enclosing said gas in said reservoir by means of electrostatically adhering the specimen to the specimen table; a process for controlling the pressure of a treating chamber to a given treating pressure;
 a process for transmitting heat between said specimen and said specimen table using said gas enclosed in said reservoir as well as for treating said specimen with plasma under said treating pressure in said treating chamber.

12. A treatment apparatus for treating a treated object under a reduced pressure environment, which comprises:
 means for electrostatically adhering a treated object to a specimen table after the treated object is mounted on the specimen table in a gas environment of a treating system having pressure higher than treating pressure;
 means for controlling the pressure of a treating chamber to a given treating pressure;
 means for treating said treated object under said treating pressure in said treating chamber.

13. A treatment apparatus for treating a treated object under a reduced pressure environment, which comprises:
 means for electrostatically adhering a treated object to a specimen table after the treated object is mounted on the specimen table in a gas environment of a treating chamber having pressure higher than treating pressure;
 means for controlling the pressure of said treating chamber to a given treating pressure;
 means for treating said treated object under said treating pressure in said treating chamber.

14. A treatment apparatus for treating a treated object under a reduced pressure environment, which comprises:
 means for electrostatically adhering a treated object to a specimen table after the treated object is mounted on the specimen table in a gas environment of a spare treating chamber having pressure higher than treating pressure;
 means for controlling the pressure of a treating chamber to a given treating pressure;
 means for treating said treated object under said treating pressure in said treating chamber.

15. A treatment apparatus for treating a treated object under a reduced pressure environment, which comprises:
 means for electrostatically adhering a treated object to a specimen table having a reservoir after the treated object is mounted on the specimen table in a gas environment of a treating system having pressure higher than treating pressure;
 means for controlling the pressure of a treating chamber to a given treating pressure;
 means for transmitting heat between said specimen and said specimen table using said gas enclosed in said reservoir as well as for treating said treated object under said treating pressure in said treating chamber.

16. A treatment apparatus for treating a treated object under a reduced pressure environment according to any of claim 12 through claim 15, wherein said treatment apparatus for treating a treated object is a

plasma treatment apparatus for treating a treated object with plasma.

17. A treatment apparatus for treating a treated object under a reduced pressure environment according to any of claim 12 through claim 15, wherein said treatment apparatus for treating a treated object is a treatment apparatus for treating a treated object with ion implantation.

18. A treatment apparatus for treating a treated object under a reduced pressure environment according to any of claim 12 through claim 15, wherein said treatment apparatus for treating a treated object is a molecular beam epitaxy treatment apparatus for treating a treated object with molecular beam epitaxy.

19. A treatment apparatus for treating a treated object under a reduced pressure environment according to claim 15, wherein said specimen table comprises an electrostatic adhering electrode having radially extended grooves on its surface and a hole for a pin for lifting up the specimen, and said reservoir enclosing the gas having a pressure higher than said treating pressure is between said wafer and the space that is formed from the grooves on said electrostatic adhering electrode to the gap between the pin for lifting up the specimen and the hole.

20. A treatment apparatus for treating a treated object under a reduced pressure environment according to claim 15, wherein said reservoir enclosing the gas having a pressure higher than said treating pressure is mounted on said specimen table and is opened to the surface of the electrostatic adhering electrode.

21. An electrostatic adhering apparatus for holding a wafer to be treated with plasma by electrostatic adhering force produced between the wafer and an insulating film, wherein the heat transfer coefficient between the wafer and the insulating film has a non-uniform distribution.

22. An electrostatic adhering apparatus according to claim 21, wherein the non-uniform distribution in the heat transfer coefficient is produced by means of forming contact portions and non-contact portions on the wafer alternately with varying the gap between the wafer and the insulating film.

23. An electrostatic adhering apparatus according to claim 21, wherein the non-uniform distribution in the heat transfer coefficient is produced by means of forming large roughness portions and small roughness portions alternately on the surface of the insulating film.

24. An electrostatic adhering apparatus according to claim 21, wherein the non-uniform distribution in the heat transfer coefficient is produced by means of forming the insulating film using different kinds of materials alternately.

25. An electrostatic adhering apparatus according to claim 22, wherein the gap between the wafer and the insulating film is formed by ultrasonic machining.

FIG. 1

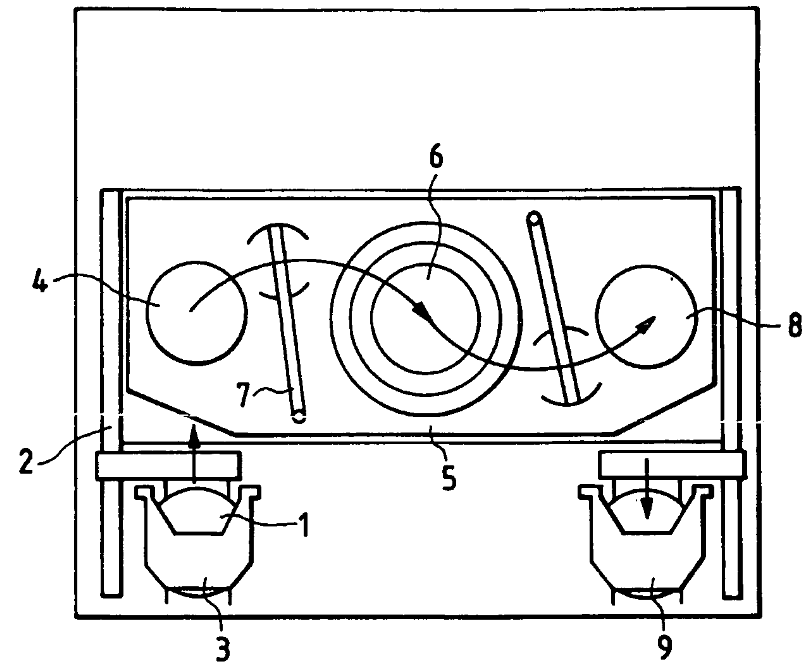
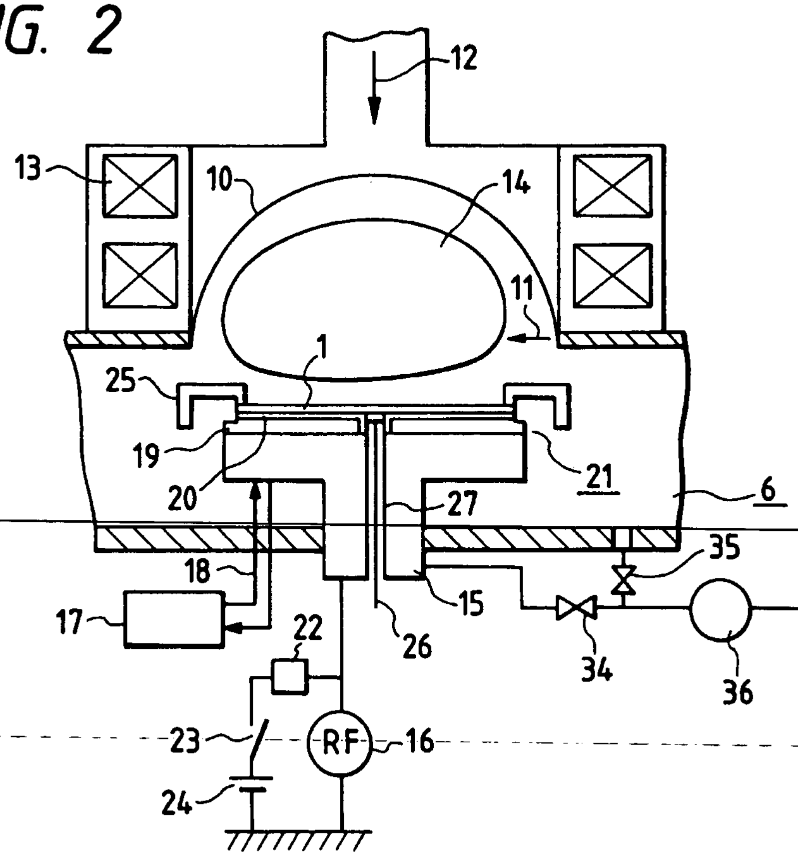

6
4
8
7
2
5
1
3
9

FIG. 2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13
10
14
11
1
25
19
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21
6
27
18
35
17
15
34
36
22
26
23
RF
16
24

FIG. 3

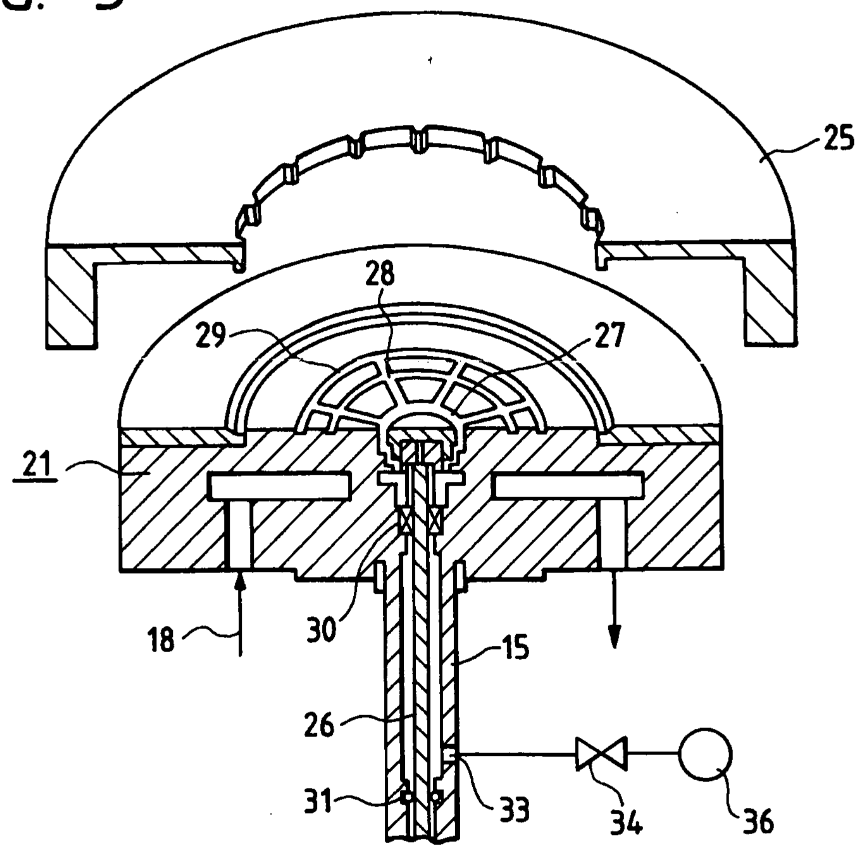


FIG. 4

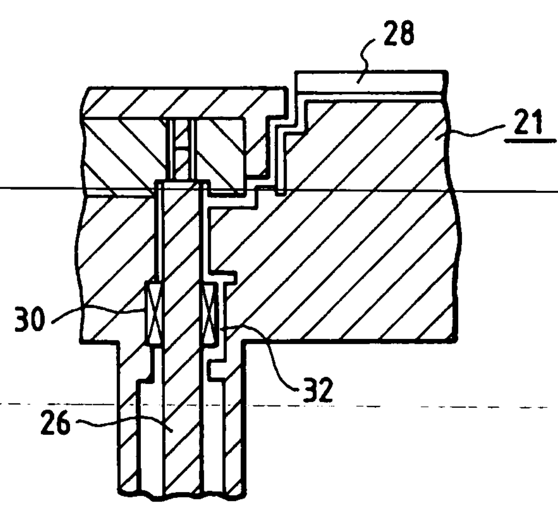


FIG. 5

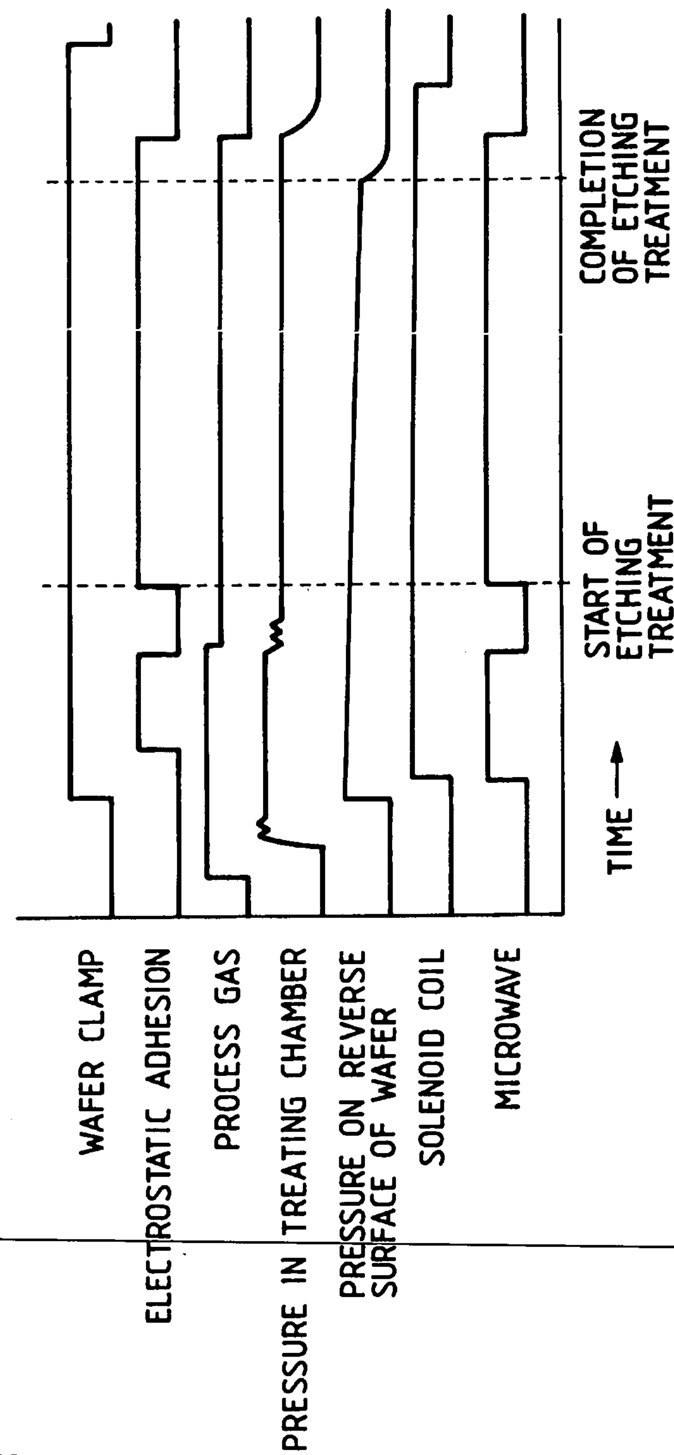

WAFER CLAMP
ELECTROSTATIC ADHESION
PROCESS GAS
PRESSURE IN TREATING CHAMBER
PRESSURE ON REVERSE SURFACE OF WAFER
SOLENOID COIL
MICROWAVE
TIME
START OF ETCHING TREATMENT
COMPLETION OF ETCHING TREATMENT

FIG. 6

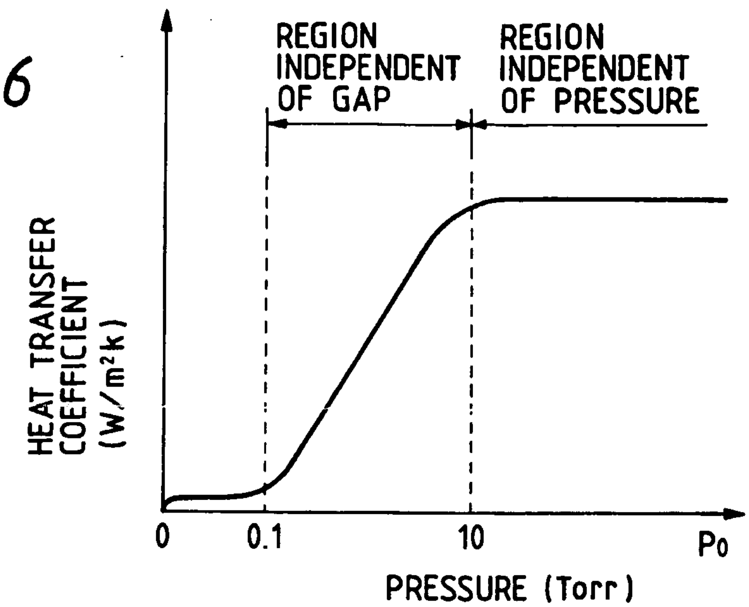
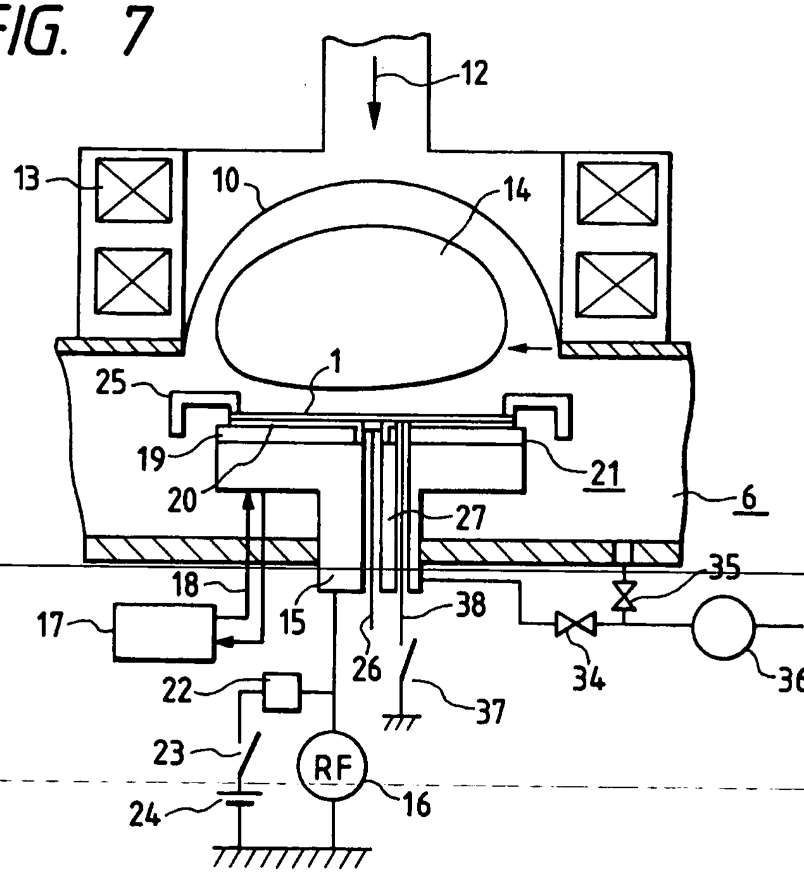

REGION
INDEPENDENT
OF GAP
REGION
INDEPENDENT
OF PRESSURE
HEAT TRANSFER
COEFFICIENT
(W/m²k)
0
0.1
10
Po
PRESSURE (Torr)

FIG. 7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13
10
14
1
25
19
20
21
6
27
18
15
17
38
26
35
34
36
37
22
23
RF
24
16

FIG. 8

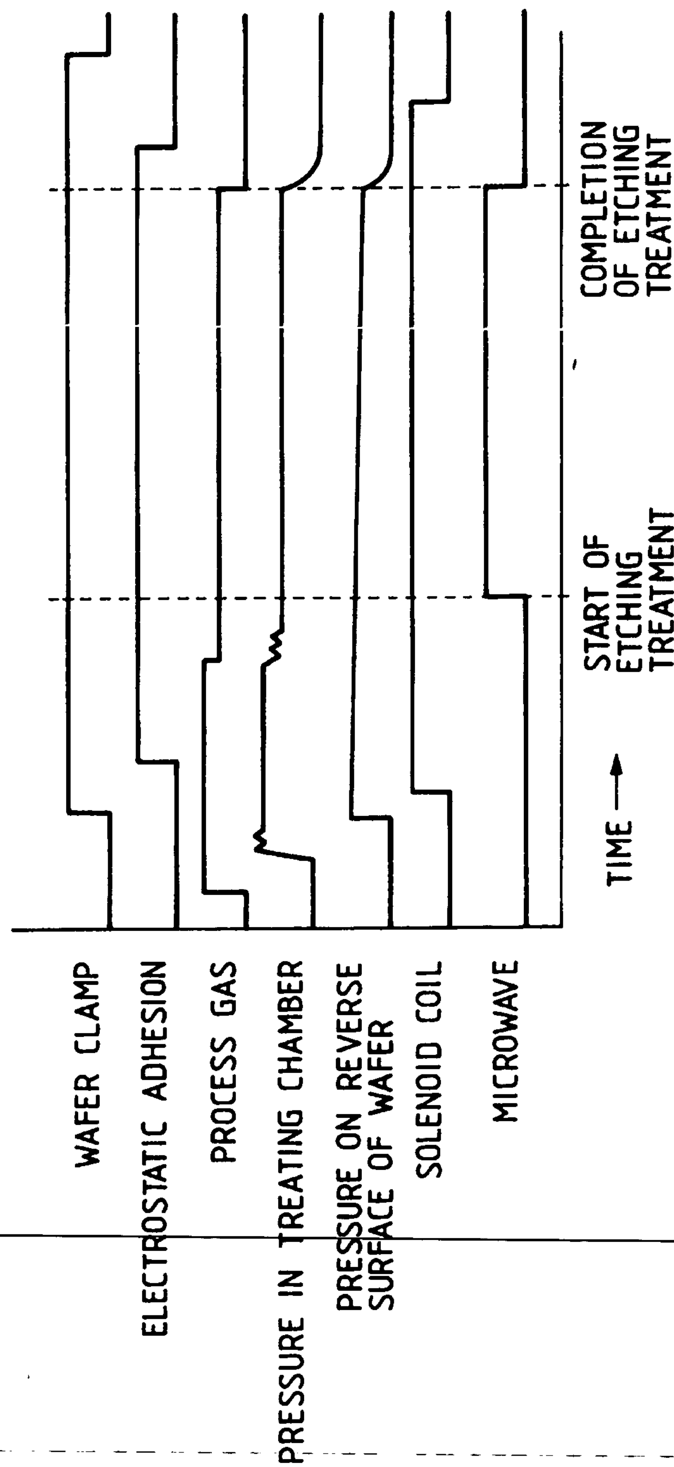

WAFER CLAMP
ELECTROSTATIC ADHESION
PROCESS GAS
PRESSURE IN TREATING CHAMBER
PRESSURE ON REVERSE SURFACE OF WAFER
SOLENOID COIL
MICROWAVE
TIME
START OF ETCHING TREATMENT
COMPLETION OF ETCHING TREATMENT

FIG. 9

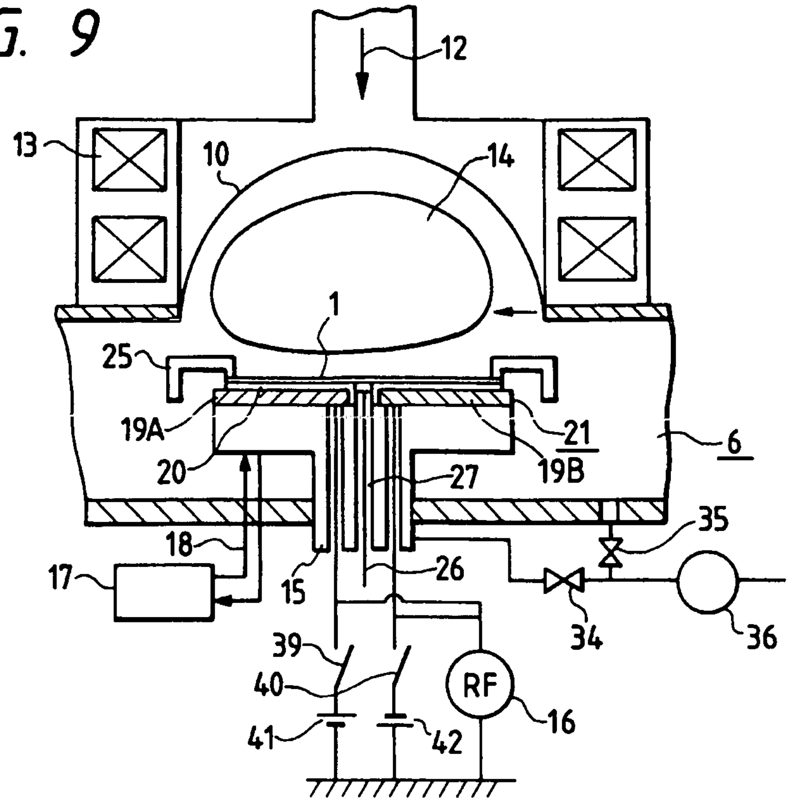
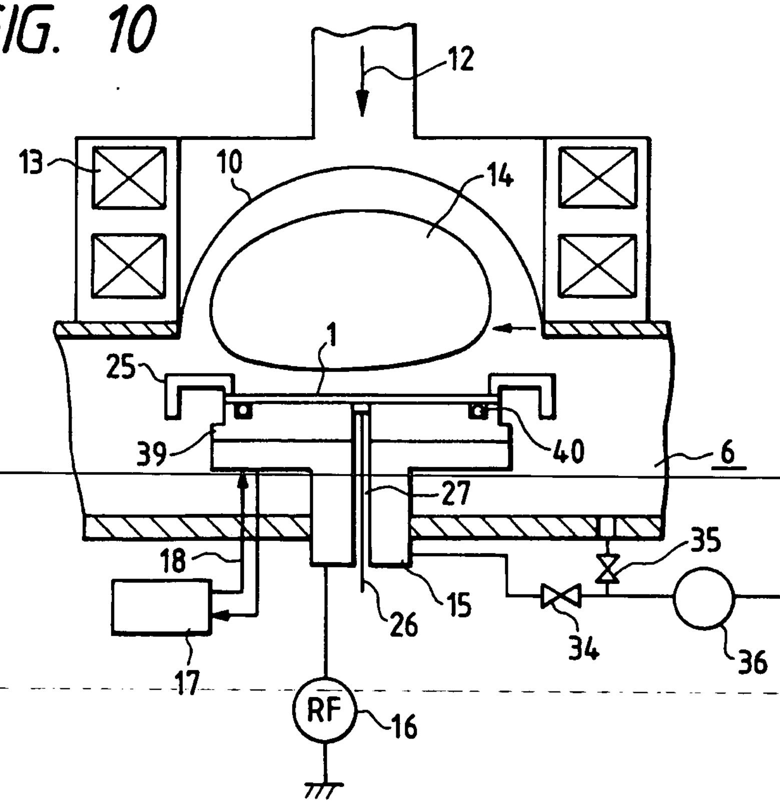

12
13
10
14
1
25
19A
20
21
19B
6
27
35
18
17
15
26
34
36
39
40
RF
41
42
16

FIG. 10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6
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26
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34
36
17
RF
16

FIG. 11

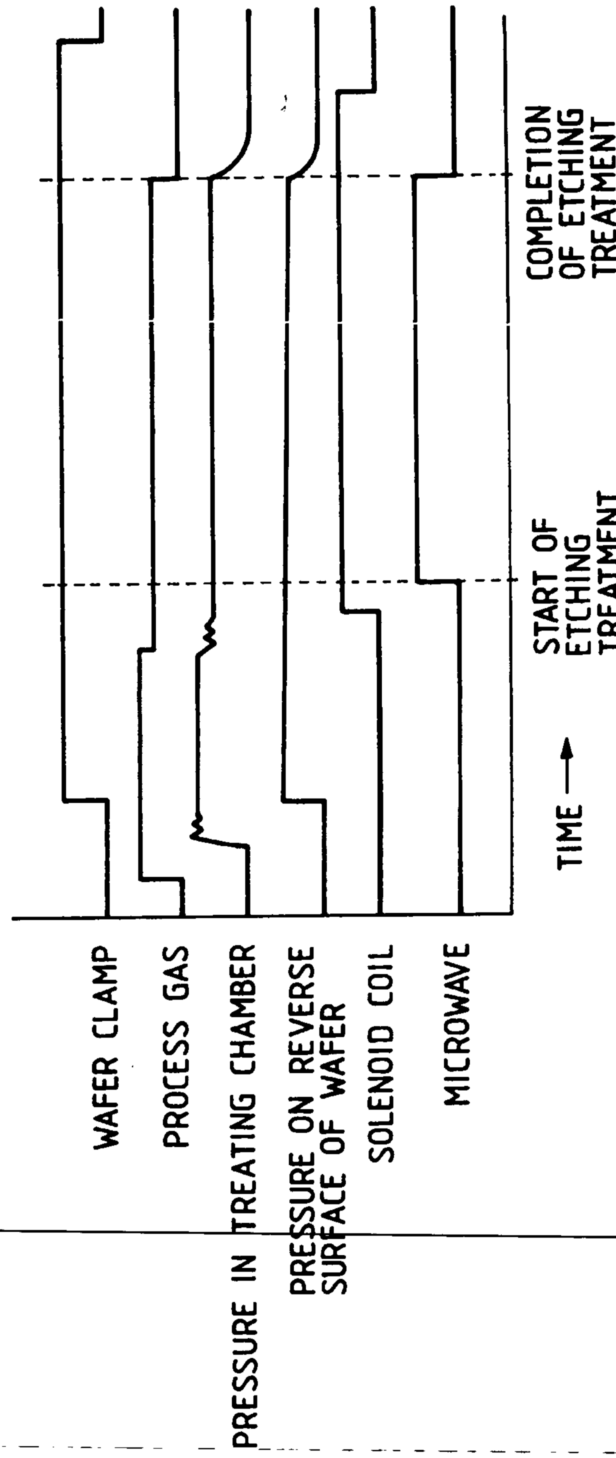
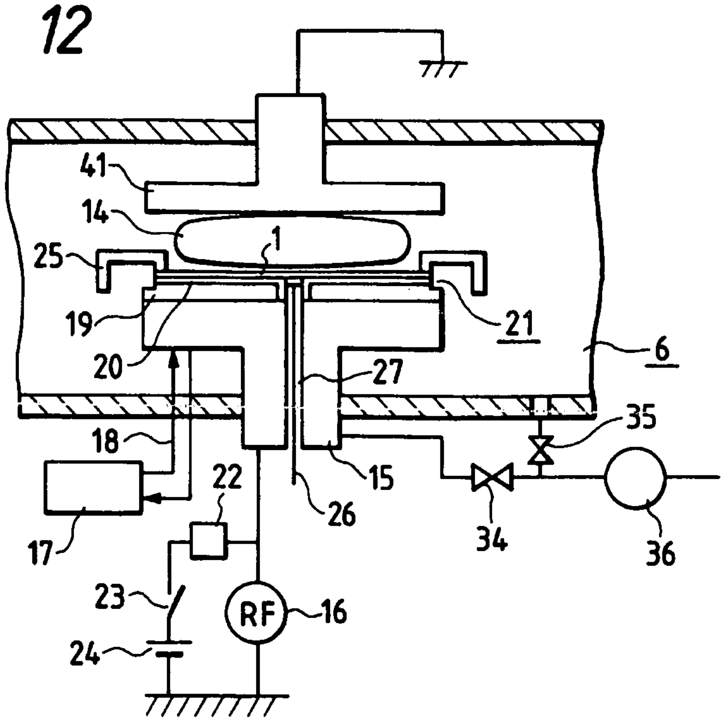

WAFER CLAMP
PROCESS GAS
PRESSURE IN TREATING CHAMBER
PRESSURE ON REVERSE SURFACE OF WAFER
SOLENOID COIL
MICROWAVE
TIME
START OF ETCHING TREATMENT
COMPLETION OF ETCHING TREATMENT

FIG. 12


41
14
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18
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15
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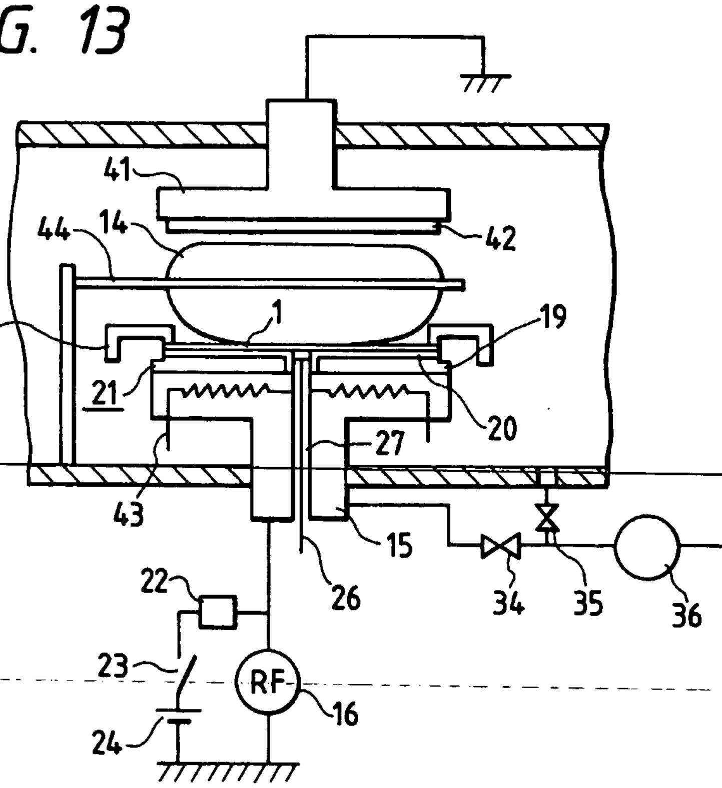
34
36
17
23
RF
16
24

FIG. 13


41
42
44
14
1
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27
43
15
26
34
35
36
22
23
RF
16
24

FIG. 14

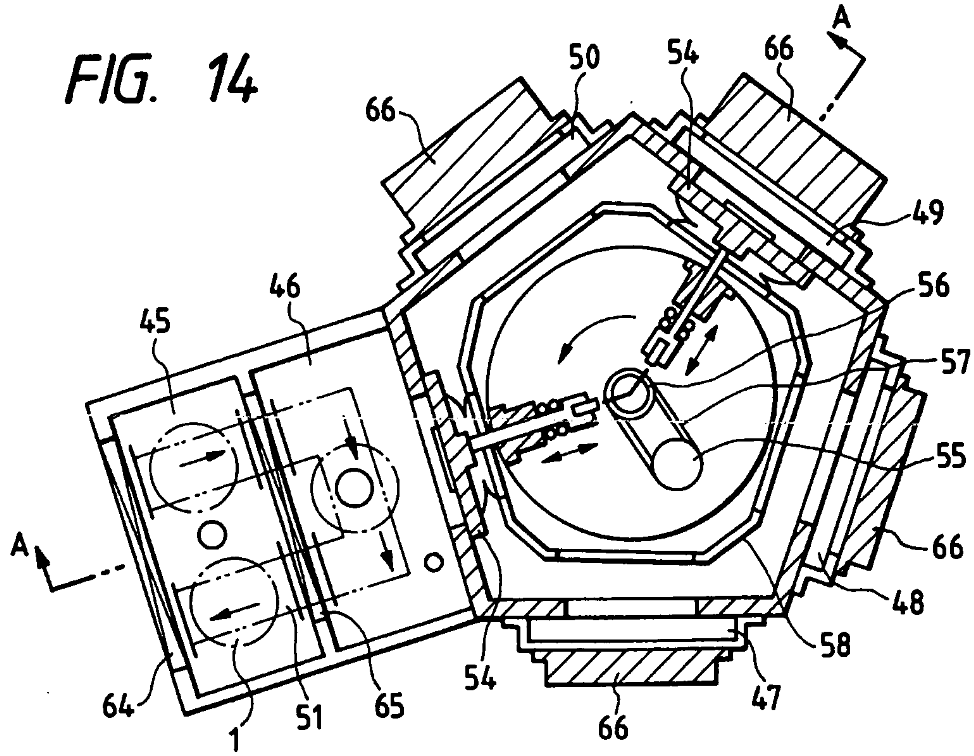
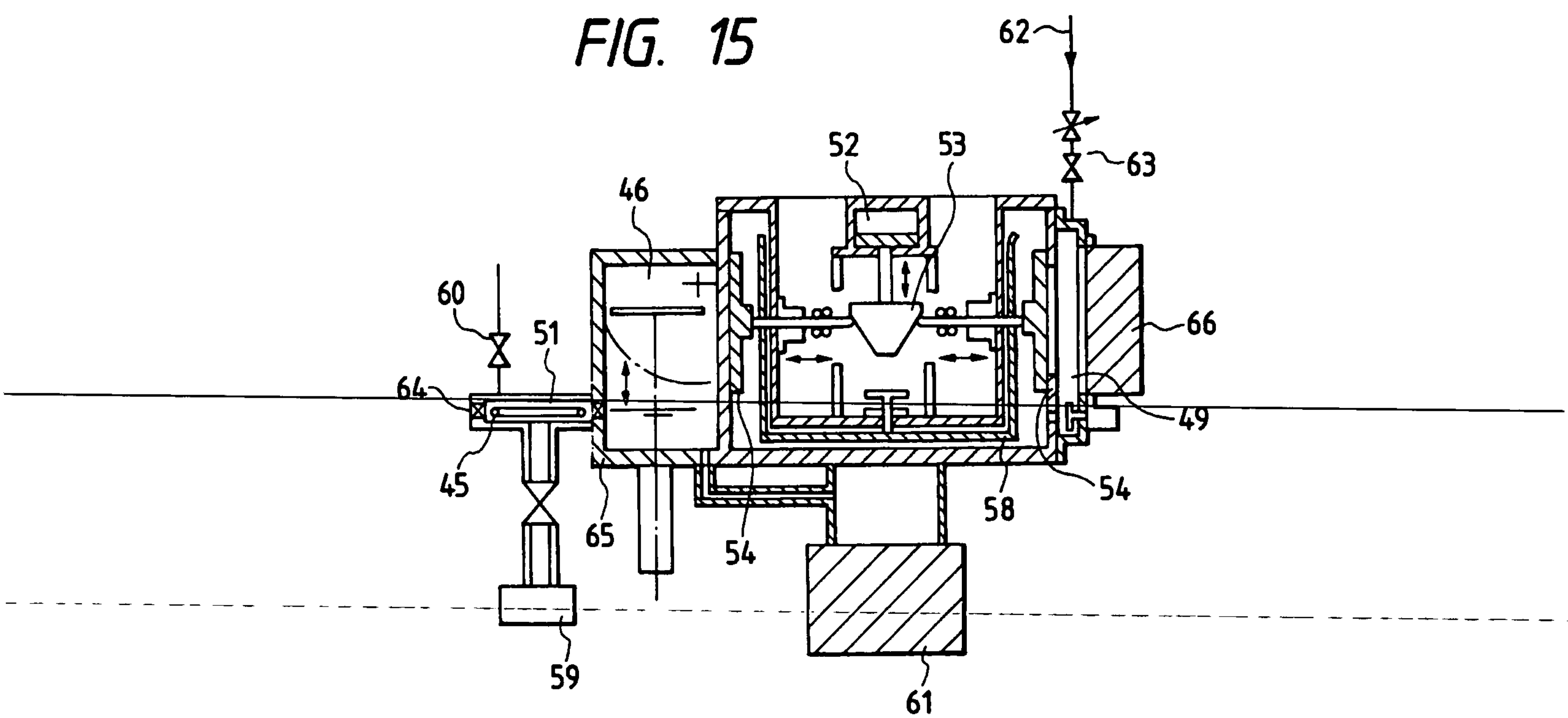

A
50
54
66
66
49
56
57
55
66
48
58
47
66
54
46
45
A
64
1
51
65

FIG. 15


62
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46
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51
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66
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45
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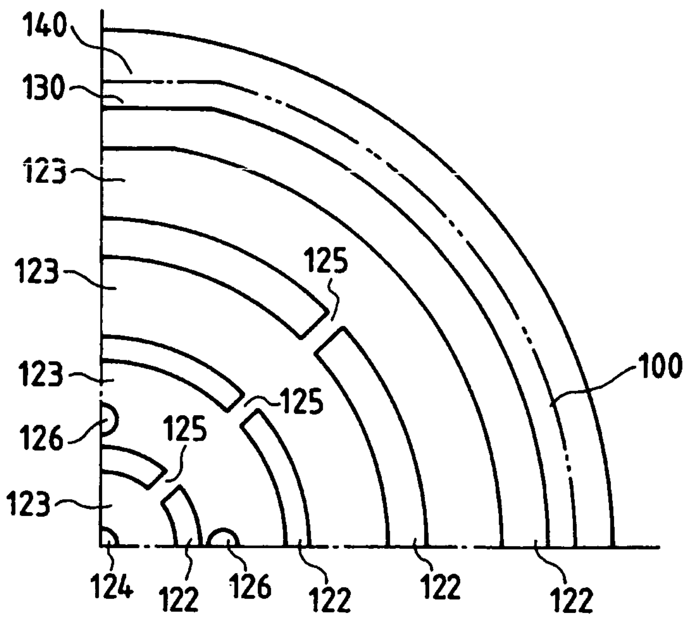
54
58
54
59
61

FIG. 16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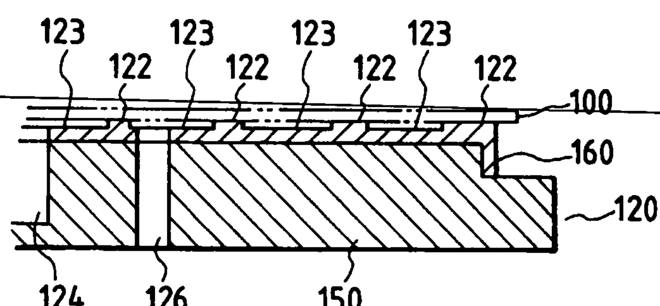
123
123
125
123
125
126
125
123
100
124
122
126
122
122
122

FIG. 17


123
123
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123
122
122
122
122
100
160
120
124
126
150

FIG. 18

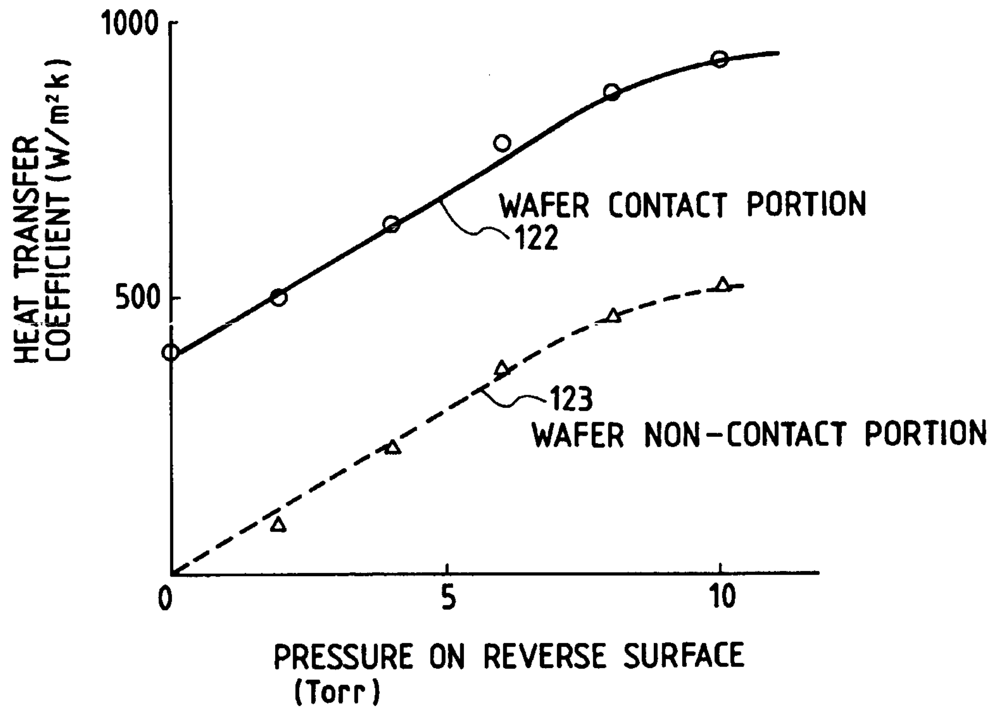
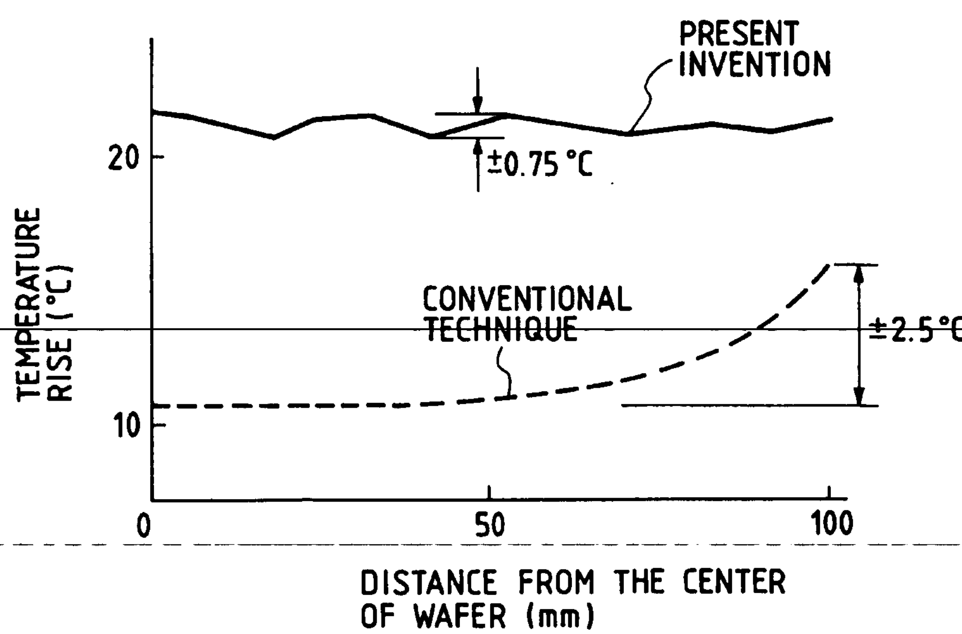

1000
500
HEAT TRANSFER COEFFICIENT (W/m²k)
WAFER CONTACT PORTION
122
123
WAFER NON-CONTACT PORTION
0
5
10
PRESSURE ON REVERSE SURFACE (Torr)

FIG. 19


PRESENT INVENTION
±0.75 °C
20
10
TEMPERATURE RISE (°C)
CONVENTIONAL TECHNIQUE
±2.5 °C
0
50
100
DISTANCE FROM THE CENTER OF WAFER (mm)

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 94 10 8878

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	IBM TECHNICAL DISCLOSURE BULLETIN., vol.31, no.1, June 1988, NEW YORK US pages 462 - 464, XP119644 'ELECTROSTATIC WAFER HOLDER FOR WAFER COOLING DURING REACTIVE ION ETCHING' * the whole document *	1-5,7,8, 11-16, 20-22,25	H01L21/00
X	EP-A-0 513 834 (APPLIED MATERIAL) * the whole document *	7,9,18, 19	
X	EP-A-0 469 469 (TOKYO ELECTRON) * the whole document *	6,10,17	
A	US-A-5 213 349 (ELLIOT)		
A	EP-A-0 260 150 (KABUSHIKI)		
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			H01L

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	25 July 1994	Bertin, M

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document